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Coalbed Natural Gas Resources and Produced Water Management Issues

Private and government emphasis in recent years has stressed the growing importance of natural gas as a prime source of energy for industrial power and residential heating needs in the United States. Currently coalbed natural gas is supplying 8% of the US natural gas. This edition of the *EYE on Environment* will focus on produced water issues associated with the production of coalbed natural gas.

INTRODUCTION

Coal is the most abundant energy source in the world, and it is a major source of hydrocarbons, particularly gas. Coalbed Natural Gas (CNG) formerly termed coalbed methane (CBM) represents a significant energy resource in this country. During CNG production large volumes of water are pumped to the ground surface to lower the pressure in the coalbed reservoirs and to stimulate the release of methane from the coal.

BACKGROUND

Coalbed natural gas can be used as an energy source that is environmentally acceptable. Coal deposits are widespread, underlying 13% of the United States. The in-place coalbed natural gas resources of the United States are estimated to be more than 700 trillion cubic feet (Tcf), but less than 100 Tcf may be economically recoverable. The key to economic production of coalbed natural gas is often the handling of the large volumes of produced water. Estimates of coalbed natural gas recoverable reserves, volumes of produced water, and CNG production were provided by the United States Geological Survey (USGS), the Bureau of Land Management (BLM), various state geological surveys, and the U. S. Department of Energy.

Coals are ranked by hardness with most of the hard coals found in eastern basins. Eastern hard coals have less water and this is normally of low quality, and unsuitable for drinking or agricultural use. In addition many eastern coals do not have enough water to be removed from the coals to initiate methane or natural gas production. Coals in the western US are younger in age, typically softer, produce significantly more water, and the water is higher quality. Coal seams in the western United States are often the aquifers for drinking water.

Data from the USGS (**Figure 1**) illustrates the vast coal producing basins in the Rocky Mountain region showing the complex federal and state land ownership, which affects mineral leases, coalbed natural gas production, and environmental

Coalbed Natural Gas Issue

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This edition of Eye on Environment highlights CNG produced water management issues regulations for produced water. Eastern basins (Illinois Basin, the Appalachian region, the Black Warrior Basin, the Gulf Coast and the mid-continent Kansas, Oklahoma, Arkansas region) also produce CNG; however produced waters from these areas have higher concentrations of chlorides and dissolved solids than produced water from most western basins, which preclude them from most beneficial uses of CNG produced water.

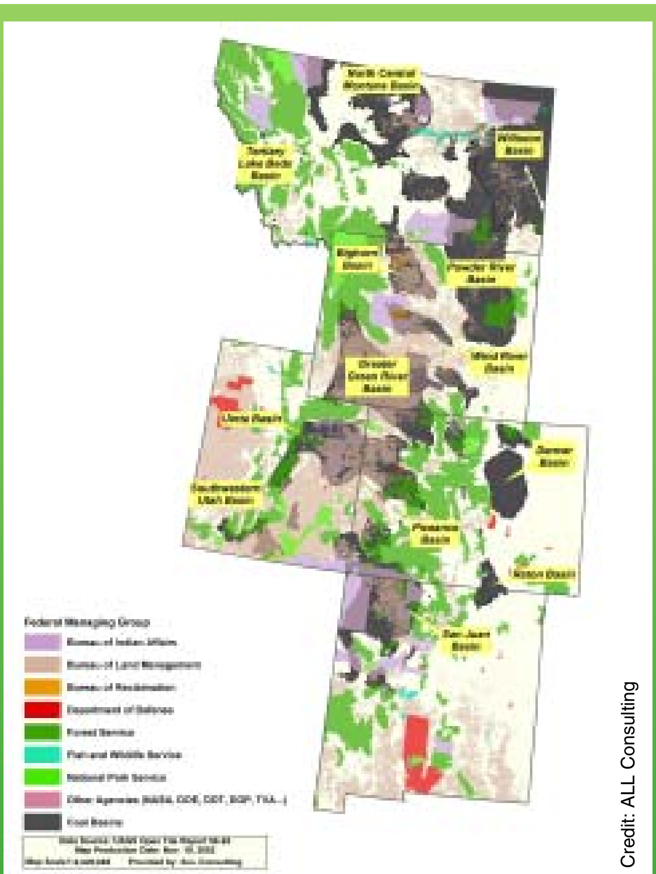


Figure 1. Map showing coal basins within the study area as well as land ownership distribution. Source: USGS Open file report 96-92.

REGIONAL CNG RESOURCE DEVELOPMENT

To produce CNG from coal seams a series of wells are drilled to pump groundwater to the surface to reduce the hydrostatic pressure in the coalbeds. Once the fluid pressure in the coalbed is released, natural gas or methane is released. **Figure 2** shows a schematic of a CNG production well. The produced water is high in volume early in CNG development, but the volume of water is reduced dramatically over the life of the well. Produced water quality varies from meeting federal drinking water standards up to concentrations of 180,000 ppm Total Dissolved Solids (TDS). In general groundwater quality in the west is higher than in eastern basins.

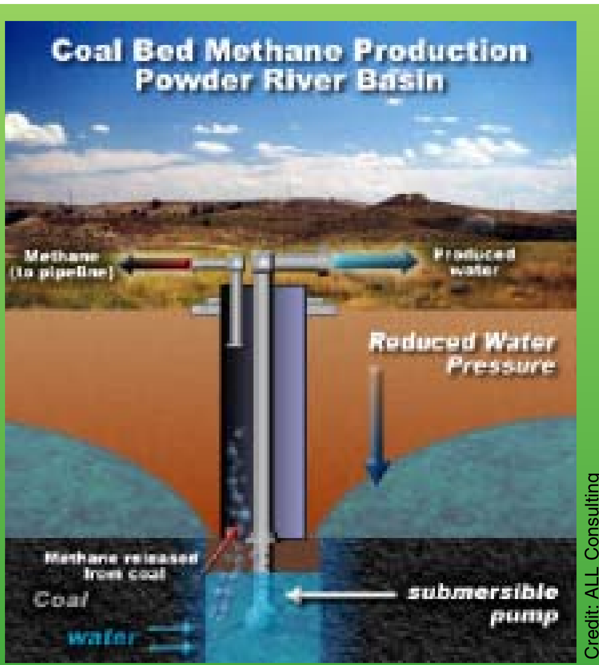


Figure 2. The hydrostatic pressure drops by producing water from a coalbed natural gas well.

Water problems associated with coalbed natural gas production are significantly higher in the western US than in the east. The necessary water to pump out CNG wells to desorb the natural gas involves water right issues. The potential for wasting useable groundwater and the disposal costs of produced water are serious environmental issues. In the arid west, useable water must be conserved for beneficial uses. CNG production raises two concerns; depleting ground water and lowering local water tables, which could cause residential and agricultural wells to go dry.

CNG developers are expected to manage groundwater production, find beneficial uses for produced water, and at the same time minimize or remediate any negative impacts produced water may have on the environment. To understand the potential effects and uses of coalbed natural gas produced water, it is essential to review the resources of CNG producing areas, both for historical production and future potential.

Alaska is new to coalbed natural gas production (first well – 1994), but has great potential for development, and production would benefit remote rural communities as well as larger cities and towns. Reserve estimates for Alaska are as high as over one quadrillion cubic feet of coalbed natural gas.

The Black Warrior Basin in Alabama is one of the oldest CNG plays in the United States. Coal degasification projects in the early 1980s led to a rapid expansion of coalbed natural gas production. As of 2002 there were 3,250 active CNG wells in the Black Warrior Basin with reserves of 20 Tcf. Produced water quality is typically low with TDS's in excess of 30,000 ppm.

The large Gulf Coast region extending west from the Mississippi Embayment, across Alabama, Mississippi, Louisiana, Arkansas, and Texas into northern Mexico contains a number of coal bearing formations with total reserves of .4 to 8 Tcf (USGS estimate). Groundwater quality across this area is highly variable, and CNG production in the region is minimal at this time.

The Illinois Basin contains the largest deposits of coal in the United States; however, test wells for CNG drilled in Illinois, Indiana, and Kentucky indicate commercial coalbed natural gas production is limited. Groundwater in the Illinois Basin is low quality and a significant portion is contaminated due to previous coal mining activities.

The extensive coal deposits of the Appalachian Basin range across Pennsylvania, West Virginia, Ohio, Kentucky, Maryland, Tennessee, Virginia and the Black Warrior Basin of Alabama. CNG is heavily commercialized in Virginia and Alabama, and moderately developed in Pennsylvania, West Virginia, and Kentucky. Reserve estimates for the Appalachian Basin range from 60 to 76 Tcf. The water conditions in the Appalachian Basin are highly variable, but typically produced water contains above 10,000 ppm TDS, high in metals, sulfur and arsenic.

Arkoma-Cherokee Basins - The Cherokee Platform covers parts of SE Kansas, SW Missouri, and NE Oklahoma, while the Arkoma Basin extends from central Arkansas into central Oklahoma. Due to recent changes in the Tax Credit laws, CNG development in this region has expanded greatly in the past decade. The produced water in the region is very high in TDS up to 90,000 ppm, and is normally injected into the underlying Arbuckle formation.

"The Inter-Mountain West holds a vast promise for America's future natural gas supply."

– Diemer True, Independent Petroleum Association of America, Chairman, June 2003

The Powder River Basin of Wyoming and Montana has become the hottest CNG play of the past decade, and its large volumes of produced water have caused considerable public concern and controversy. By early 2002 over 9,000 CNG wells were operating in the Wyoming portion of the basin, an over 10-fold increase in only three years. Production in 2002 averaged over 25 MMcf per day in Wyoming. Reserves are estimated at 90 Tcf for the Montana portion of the Powder River Basin, and increased development is anticipated now that the Bureau of Land Management (BLM) has completed the Environmental Impact Statements (EIS). The BLM estimates that over 60,000 CNG wells will be drilled in the Powder River Basin during the next 10 to 20 years.

The San Juan Basin of New Mexico and Colorado is one of the oldest CNG producing regions in the United States. Methane gas has been an economic resource in the San Juan Basin for 100 years. Recent annual production of CNG averages 0.9 Tcf from over 3,100 wells. The BLM estimates that in the San Juan Basin over 1,000 CNG wells will be drilled in Colorado and 3,000 in New Mexico in the near future. These wells produce an average of 25 bbl water per day per well.

Uinta Basin and Central Utah - The coals from Utah fall mainly into the Ferron Coalbed Fairway, an 80 mile corridor of basins crossing east-central Utah, containing 4 to 9 Tcf of recoverable reserves (BLM). The Utah Geological Survey data shows that CNG production provides 28% of all Utah's natural Gas. Development is expected to increase when new EIS's are completed by the BLM. Water production from CNG operations in Utah averages 215 bbl water per day per well, a significant volume of water for disposal or beneficial use with moderate TDS content ranging from 6,000 to 43,000 mg/L. Proper management of CNG produced water could favorably impact the agriculture of the region.

Colorado Plateau Basins include a number of basins in Wyoming and Colorado resulting from Laramide tectonics and deposition in the Cretaceous Western Interior Seaway. CNG reserves are moderate for the Wind River, Green River and Raton basins, but little CNG development is anticipated in the Hanna, and Denver basins and none in the Bighorn Basin.

Western Washington - Coalbed natural gas potential from Washington is estimated at 24 Tcf; however, limited testing has not resulted in commercial CNG development. Groundwater provides 65% of Washington's drinking water, and 25% of all commercial, industrial and agricultural water, so water management for coalbed natural gas development will be a prime concern.

The Williston Basin of NE Montana, North and South Dakota, and Saskatchewan and Manitoba, Canada is one of the newest regions for coalbed natural gas evaluation and development. The coals of the Williston Basin are similar in age and deposition to those of the Powder River Basin to the southwest. However, evaluations for CNG potential by the North Dakota Geological Survey indicate that the Williston Basin does not have the same potential as the Powder River Basin, and there is no current CNG development.

WATER RIGHTS AND PRODUCED WATER TREATMENT

The states with the highest potential for CNG production are in the Rocky Mountain region where water rights have been a vital issue since the 19th century. Management of CNG resources and produced water must address the impact of water use, as well as the impact of produced water on the environment. In the arid western states (Colorado, Montana, New Mexico, Utah and Wyoming) protection of high quality groundwater and prioritizing water use is governed by a complicated set of Federal and State regulations differing by state and sometimes by basin within a state. CNG operators must ground themselves in regulatory issues of the specific state and basin before attempting to produce the natural gas or dispose of the produced water.

Federal laws have sole control of water on Federal Lands and Indian Reservations, which comprise a significant portion of the Rocky Mountain region as illustrated in **Figure 1**. On private lands operators must abide by both Federal and State regulations. The United States enjoys one of the cleanest drinking water supplies in the world, and regulations on water use and management of produced water aim to maintain that standard.

The Environmental Protection Agency (EPA) has the main control over water standards, by way of the Clean Water Act (CWA), the primary guideline for discharge of all water and/or pollutants to surface water. The CWA provides standards covering biologic contamination, disinfectants, organic and inorganic chemicals and radionuclides. Most CNG produced water contaminants are inorganic chemicals, which are measured separately as Total Dissolved Solids (TDS). The EPA also maintains control of groundwater quality through the Underground Injection Control (UIC) program, which requires critical management of produced water.

Water Rights

The two basic approaches to state law are riparian and prior appropriation. Riparian laws are based on the ownership of the property through which the water flows. Prior appropriation rights rely on the principal of "first in time – first in right". Because water is often scarce in the arid parts of the western US, both of these approaches are heavily entrenched and often hotly contested in state laws and regulatory doctrine. Appropriative rights regard physical control and beneficial use of water as key elements, and address water rights by looking at intent, diversion, beneficial use and priority. The justification for beneficial use is to consider both community needs and to prevent water waste.

Produced Water Treatment and Disposal

Management costs for treatment and disposal of produced water severely impacts the economics of CNG operations in the western US where high volumes of water are produced. Regulations within each state control how produced water may be treated. These regulations reflect water quality and the potential for beneficial use. Water of poor quality is typically reinjected into subsurface formations to protect the environment of surface waters and soils. In some parts of the west deep well injection rates reported to DOE are over $4/ bbl. Treatment to reduce the volume of injected water is a vital management strategy.

Produced Water Treatment Technologies

The first step in treatment of produced water is to assess the water quality by analysis, which identifies the presence and amounts of constituents. Different methods test for individual constituents and contaminants, and for the cumulative effects of combined constituents. Standards for tests and constituent levels are set by the National Pollutant Discharge Elimination System (NPDES), which issues permits on tested water.

Quality of produced water varies from basin to basin and some treatment technologies may be applicable in one basin, but not in another basin or region. The ultimate disposal of the produced water and the types of beneficial use or discharge are determining factors in selection of treatment technologies. Current technologies are discussed below with critical review of their potential success.

Freeze-Thaw/Evaporation

The freeze-thaw/evaporation (FTE) process involves lowering the temperature of the produced water to below 32° F. Pure water freezes at this temperature and forms ice crystals of high water quality, leaving concentrated solutions of salts and solid constituents which can be removed. The FTE process is capable of removing or reducing concentrations of organic chemicals, heavy metals and particulate matter from produced water. Arid climates such as the Rocky Mountain west are particularly suited to FTE technology. Studies in the San Juan Basin of New Mexico in 1997-8 found that the FTE process was capable of reducing the volume of produced water by 80%. In North Dakota use of the FTE process on water from the Dakota aquifer yields 73% of the high quality water for use in the Grand Forks municipal water supply.

Reverse Osmosis

Hyperfiltration of water, termed Reverse Osmosis (RO) is a successful treatment method which removes TDS and some metals, such as arsenic, and bacteria in a specified range (150-250 daltons). In the past reverse osmosis has been used to convert brackish water, seawater or brines to drinking water. The process is capable of providing very high quality water by passing the water through a semi-permeable membrane. The reverse osmosis process seen in **Figure 3** utilizes a cross flow principal to continuously clean the membrane using a pump to force the water through the membrane. Because of the costs and energy involved in RO treatment, some pretreatment or filtering of produced water is necessary to prolong membrane life. Tests show that RO effectively removes 95% to 99% dissolved salts and can reduce salinity in water ranging up to 12,000 PPM.

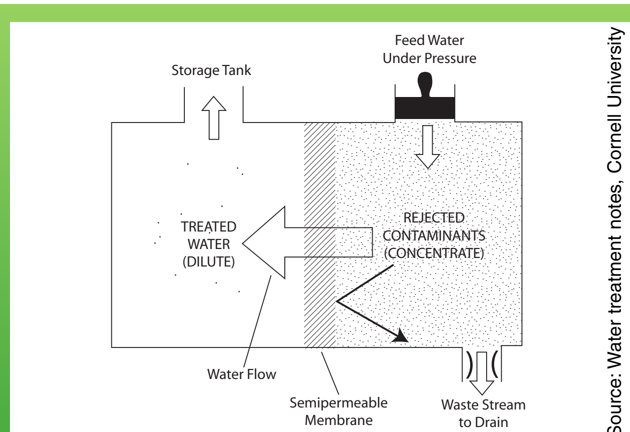


Figure 3. Reverse osmosis is used to lower total dissolved solids.

Ultraviolet Light

Ultraviolet light (UV) has a proven record for the treatment of water contaminated by microbial forms such as bacteria, viruses, fungi, algae and protozoa. The ultraviolet energy is absorbed by the cells of living forms and prevents the cell from multiplying. The amount of UV light can be varied to kill specific microbes. Pretreatment of produced water to remove minerals such as manganese, iron, calcium and magnesium, which cause hard water, is necessary as these minerals can reduce the intensity and effect of UV light. For discharge into fresh water aquifers CNG water must be sterilized at the surface and UV light can accomplish this.

UV light is often combined with ozone to enhance the reactivity of the ozone in the removal of certain organic chemical constituents. Ozone has been shown to be more effective than chlorine to treat algae and biological growth in drinking water. Although UV light and ozone treatments have superior qualities to produce high quality water, they are relatively expensive, and suitable for seriously contaminated drinking water, but not suitable or economic for most other beneficial uses.

Chemical Treatment

Chlorination has been the primary chemical water treatment method for years. Chlorine is used to disinfect municipal water supplies, sewage and industrial wastes. Chlorination has the added advantage that it continues to effect water purification long after initial application. Chlorination systems are cost-effective, safe to use, and require minimum maintenance, but water must be pretreated to remove other mineral constituents and particulate matter. Chlorinated water can be used for human consumption, livestock or wildlife management.

Iodine is used to treat water to remove pathogens primarily from human drinking water. Its safe for long-term usage in small dosages, but long term usage could lead to cumulative iodine concentrations higher than recommended dosage.

Ion Exchange

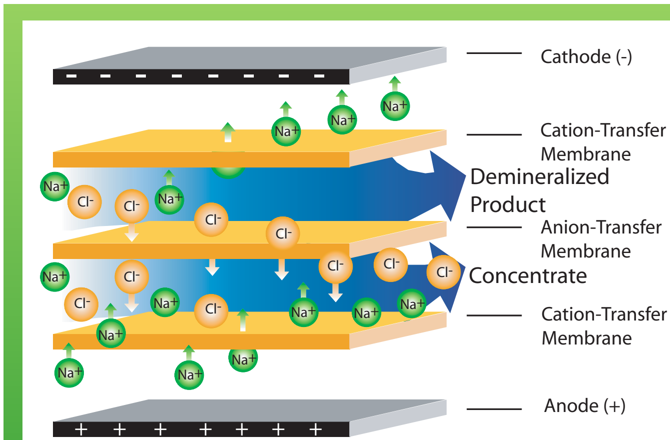
Ion exchange technology is used for residential purposes to soften water by removing ions such as calcium and magnesium, which cause hardness. Ion Exchange is low cost, requires low energy and does not pollute; but must be used in conjunction with other chemical treatments, as it removes salts and heavy metals, but can't remove organic constituents. An ion exchange method by Hydrometrics, HYDRO (patent pending) is designed specifically to treat CNG produced water. Results show that waste streams can be reduced to 4%-10% of the original volume.

Capacitive Desalination or Deionization

Capacitive desalination or deionization is a new advance on conventional desalination which holds the potential for high volume water recovery at one-thousandth to one-hundredth the energy required by standard methods. At the current level of development the technology is high cost and is intended for deionizing water for use in boilers in fossil-fueled and nuclear power plants. Preliminary tests on deionization of CNG waters were funded by the US DOE in 2002.

Electrodialysis Reversal (EDR)

Electrodialysis is similar to ion exchange, but is capable of exchanging both negative and positively charged ions alternately. Two membranes are arranged to create a space where diluted solutions are acted upon. The membranes are placed in a stack (**Figure 4**), and a pump is used to force water through the membranes. Polarities of the membranes can be reversed periodically to change the brine and water channels and to prevent buildup of slime and scales. The process operates on low energy, and because it is effectively self cleaning the membranes last longer. The process must be used in conjunction with chemical treatments to remove organic contaminants.



Source: Ionics, 2002

Figure 4. Cation and anion selective membranes are used to remove minerals from water.

Distillation

Distillation is capable of removing 99.5% of impurities from water, but traditionally the capital cost of facilities is too high for treating large volume of water. Distillation involves boiling water and condensing it to remove impurities. New technologies adapted to conventional distillation uses a rapid spray system to separate salts from water. This Rapid Spray Distillation has been tested at 95% recovery of pure water and is projected to cost one-eighth the treatment cost of other technologies, and hold promise for use in treatment of CNG produced water.

Artificial Wetlands

Artificial wetlands provide an approach which allows natural biodegradation processes to cleanse produced water. An example unit is shown from the Powder River Basin (**Figure 5**). The system is low cost to build and easy to maintain, but has a slow rate of operation. The long term use of artificial wetlands for organic removal treatment is 20 years and provides excellent wildlife habitat. Artificial wetlands habitat reproduces natural filtration systems allowing both vertical and horizontal flow of water through the system. Vertical flow through layers of soils and gravels is efficient at treating water because of the natural bacteria, which degrades many pollutants. Specific plant species have been tested and reeds with large biomass and underground root systems have proven most effective. Experiments using artificial wetlands to treat coalbed natural gas produced water found the method effective for removal of iron, and barium at a rate of 30 to 40 gallons of water per minute over a one year test.

Figure 5. Artificial wetlands allow natural biodegradation processes to cleanse produced water.

BENEFICIAL USE ALTERNATIVES

CNG output reached 4 billion cubic feet per day in 2002 with production from 20,000 wells. This represents 8% of all natural gas produced in the US. Estimates by Argonne National Laboratory for 2002 indicate over 14 billion bbl/year of produced water must be handled in the US with an increasing amount from coalbed natural gas development. Economics of CNG production depend on reducing the cost of handling produced water. Beneficial uses for produced water offer the best alternative to high cost reinjection procedures. Much of the water from CNG development in the Rocky Mountain region is of high quality and requires no or only moderate treatment prior to agricultural or industrial use. Beneficial uses of CNG produced water fall in three main categories: surface discharge including agricultural use; water impoundments for stock and wildlife, and recreation; and industrial uses. These categories have some overlap due to drainage characteristics and storage requirements.

Surface Discharge

The key to surface discharge used to augment stream water flow is management of discharge amounts; timing and impact on the surface streams. The Clean Water Act requires permits for all water discharges; specifying volumes of water, TDS content, and the body of water receiving the discharge. After discharge the water becomes part of the "waters of the state" and is subject to all regulations applicable to surface water. Individual states have specific regulations–typical considerations require characterization of the stream; the total maximum daily load of pollutants in a stream segment, the base flow, the biological environment potentially affected, the primary source of water, the type of point source for any pollutants, the size and type of stream (perennial, intermittent, or ephemeral, and the affect of snowmelt on stream flow.

There are three methods of surface discharge; discharge to surface water, discharge to land surface with possible runoff (agricultural uses), and discharge to land surface with possible infiltration into subsurface aquifers (impoundments). Direct discharge by pipelines avoids the potential erosion affects of open channel discharge. The volume of direct discharge must also be considered, so that abrupt changes in the height of the water in a channel does not cause adverse affects on plant life, bank stability, aquatic vegetation, fish or invertebrates; all of which have particular depth and flow requirements.

Water Impoundments

Wildlife and livestock water impoundments

Wildlife watering ponds provide adequate drinking water during drought periods, create or expand suitable habitat for wildlife and may improve water quality. Because the arid western states have broad areas with inadequate surface water and prolonged periods of drought, creation of ponds using CNG produced water can be highly beneficial to resident species of deer, pronghorn, coyotes, bobcats, upland game and shore birds, and provide breeding and wintering areas for waterfowl. Ponds can be used to increase the range of certain wildlife species into areas which previously did not have sufficient surface water.

Livestock watering practices often rely on access to natural streams and lakes. In many areas this has caused erosion and destabilization of stream banks, increased sediment load and contamination caused by increased nutrients and resulting algae bloom. The use of off-channel watering facilities and CNG produced water ponds could provide additional water sources; allow the expansion of livestock grazing to areas otherwise not suitable due to limited surface water; and would significantly reduce negative impacts of livestock on natural streams. **Figure 6** shows a simple stock watering setup using a large equipment tire.

Photo credit: ALL Consulting

Figure 6. Stock watering device utilizing produced water provides stock and wildlife the ability to occupy grazing areas without adequate surface water.

The Natural Resource Conservation Service (NRCS) has nationwide standards and design guidelines for wildlife and livestock watering facilities. Ponds for year round water impoundment for wildlife, migratory birds and fish must be at least 40 to 400 acres in size with 25% of the area over 3 meters deep. Other requirements include fencing to protect livestock, water valves, and maintenance. The quality of CNG produced water in much of the Rocky Mountain region meets standards for wildlife and livestock watering.

Wildlife Fisheries

Off-channel ponds, of sufficient size to be maintained as fish breeding habitat, range in size from small private ponds to large reservoirs and lakes. When conditions of size, depth and accessibility are met State agencies will stock the ponds with the appropriate species of fish for the region. State, Federal and commercial fisheries are established to provide fish for restocking and for commercial resale and consumption. The Bureau of Land Management (BLM) manages over 85,000 miles of fishery habitat on public lands in the US. CNG produced water has the potential to expand the number of fisheries and areas where they can be established. Requirements for fish ponds differ from state to state, but primarily specify pond size, depth, year round water capacity, erosion prevention, livestock fencing, and control of flow. In Wyoming untreated CNG produced water has been used to establish ponds for rainbow trout, blue gill and small-mouth bass.

Recharge Ponds

Recharge ponds are reservoirs constructed as off- or on-channel holding ponds, frequently called storm water ponds, retention ponds or wet extended detention ponds. Recharge ponds function as a permanent water management effort for seasonal surface water discharge. They may serve merely to restore depleted groundwater by water infiltration into the subsurface or may serve primarily to improve water quality, or to minimize peak flow periods and flooding. Recharge ponds lower the Total Dissolved Solid (TDS) content and thus, can serve as a CNG produced water treatment in addition to beneficial use of the impounded water.

Design of recharge ponds specifies: pretreatment, treatment, conveyance, maintenance reduction and landscaping. Pretreatment involves filtration or an interval to allow the sediment to settle prior to input into the recharge pond. Various treatments may be used to eliminate pollutants. Control of water flow and volume in the pond, pond size and spillway design fall into the conveyance category. Landscaping ponds increases the aesthetic appeal and may contribute to improved maintenance of slopes and reduced erosion and often improves local wildlife habitat.

Recreation

Recreational use of large man-made water bodies has become an important secondary function of lakes and water sources created or expanded for urban and industrial water supplies. Fishing, swimming, boating, camping facilities and waterfowl hunting are the most common recreational uses for impounded water. CNG water can be used to supply artificially constructed impoundments or to supplement natural lakes during seasonal low periods.

Evaporation Ponds

Evaporation ponds, constructed in off-channel areas provide storage for CNG water, and a relatively low-cost disposal method for CNG produced water. As evaporation occurs, the remaining water becomes concentrated into a high TDS brine, which can be processed or removed. Ponds may need to be lined with bentonite clays to prevent water infiltration into the soil.

Constructed Wetlands

Wetland systems provide duel benefits as a means of naturally treating CNG produced water and to enhance and increase wildlife habitat. Wetland construction requirements are specific to locality, but in general require a gentle gradient to prevent water runoff; and soils with silt, loam, clay and find sand which are able to hold water. Plant species should be selected given consideration to the local climate, tolerance levels to possible TDS concentration in the CNG produced water and their value as food and habitat for fish and wildlife. Early stages in wetland construction and the resulting increased vegetation are shown in **Figure 7**.

Photo credit: ALL Consulting

Figure 7. Before and after vegetation in wetland irrigation.

Agricultural Uses

CNG produced water for crops or to support pasture growth is an effective use in the arid western states where CNG produced water is normally high quality. Agricultural water sources in the west are limited by low rainfall and snowmelt normally a cumulative amount of less than 20 inches per year. The runoff into ephemeral streams is seasonal and marginal dry land farming can be improved with increased water supplies. Storage of CNG produced water in impoundments can alleviate the seasonal problems and provide irrigation water as needed for crops.

Plant sensitivity research can be used to select agricultural crops, which grow in areas of limited rainfall, colder temperatures and shorter growing seasons found in most of the Rocky Mountain states. DOE sponsored studies at Montana State University have found that barley, wheat, sugar beets, sorghum and cotton are best suited to irrigation by CNG produced water in the Powder River Basin. Native high salt tolerant grasses and forbs can be planted around impoundments and discharge sites to maximize the use of CNG produced water and reduce erosion, and are used in bioremediation of brine contaminated soils.

Sprinkler systems are used to provide a slow discharge of water over a wide area. Selection of the best irrigation system for a given area looks at several criteria; soil type (infiltration rate), system size or length, sprinkler head and capacity (spray nozzle or oscillating), area of coverage, elevation differential from pivot point to end of system, water pressure (pump capacity), speed of rotation, and peak daily evaporation. Center-pivots, side-rolls (**Figure 8**) and fixed or mobile water-guns are irrigation systems that have been used with CNG produced water in the Powder River Basin of Wyoming. Ideal conditions for CNG produced water for irrigation are areas with coarse-textured soil and salt tolerant crops. Flood irrigation using a series of constructed channels to divert water to native grass pastures has also been applied. One advantage of flood irrigation is that less water is lost through evaporation, but it is more difficult to spread the effects of the water over wide areas.

Figure 8. Side-roll irrigation unit in the Powder River Basin.

Industrial Uses

CNG produced water can be used in the operational activities of industries in the producing region. Common industrial uses include: coal mines, animal feedlots, cooling towers, car washes, enhanced oil recovery and fire protection.

Coal mines

Coal mines can use CNG water for drilling operations, dust abatement, support on conveyor belts, crushing and grinding, assistance in restoring abandoned mine sites, and to prevent spontaneous combustion of coal both in the subsurface and in storage areas.

Animal feedlots

Use of CNG produced water for animal feedlots has two applications, livestock watering and management of animal wastes. EPA regulates the disposal of animal waste streams based on the number of animals held in a given facility, and water is used to dilute animal wastes prior to discharge or disposal.

Cooling towers

Numerous industries, chemical plants and municipal power generating plants require large quantities of water as a cooling agent. Cool water enters the system and is recycled through heat exchanges and cooling ponds removing heat generated by the activities of the industrial complex. Constant input of water is necessary due to loss by evaporation.

Field and Car wash facilities

Construction activities require washing vehicles to avoid spreading noxious plants to other areas. This is particularly important when equipment is being used for reclamation of disturbed sites. Field sites and car washes in rural areas can be supplied with CNG produced water.

Enhanced Oil Recovery

When oil and gas fields are located in proximity to CNG producing areas the use of produced water from CNG activities for water flooding or secondary recovery is possible. Waterfloods are a common practice that can be performed with varying quality water.

Fisheries

Commercial fisheries in the western US obtain water rights to divert water into their operational ponds from surface waters, and CNG produced water could be economically used in place of diverted surface or groundwater. The water must be of sufficiently high quality not to be toxic or hazardous to the fish.

Fire protection

Supplies of water for nearby municipal fire hydrants and sprinkler systems are a valuable use of CNG produced water. Fighting fire does not require high quality water and use of CNG produced water would not depleting drinking water supplies. Wildfires in the western US are becoming larger and more dangerous during the drought conditions that exist in many states, and normal supplies of water for fire fighting are becoming depleted. Supplies of CNG produced water stored in impoundments could provide accessible water for fighting fires in remote western areas.

Other industrial uses

In some of the western states CNG produced water is beginning to be used in such industries as sod farming, solution mining for minerals, production of bottled drinking water and water for breweries. Sod farming using CNG produced water in the San Juan Basin is helping supply the public's increasing demand for sod in new developments in municipal areas. Uranium mines in Wyoming are using CNG produced water in solution mining of uranium ore, and companies in Nebraska, Texas and Oklahoma have submitted permits for similar operations. Some CNG produced water already falls into the range of bottled drinking water and can be sold in stores, other CNG water would require only minimal treatment to make it suitable for drinking water. Drinking water quality CNG water can be used in breweries, and less high quality CNG water can be used to irrigate barley, hops and other grains used in the manufacturing process.

Domestic and Municipal Water Use

CNG produced water which meets the drinking water standards can be used for public, residential, and municipal water use and supply. Many of the western states have a rural population in which individual landowners could benefit from a residential supply of CNG produced water, while other states have large municipalities located in or near existing and potential CNG development. In addition to providing potable water, CNG produced water may supply non-potable water uses in municipal areas, such as watering lawns, swimming pools, washing machines and plumbing.

Conclusions

CNG will play an important role in meeting the Nation's energy needs for years to come. Managing the produced water associated with CNG is a critical part on ensuring a safe, environmentally sound and affordable supply of natural gas. Many coalbed natural gas operators are actively pursuing beneficial uses for CNG produced water. The developers are undertaking a variety of new water management feasibility studies for new uses for CNG produced water that meet state and federal regulations, and provide both cost-effective water management for the CNG producers and low-cost, readily available water for public, residential, industrial uses. The strategies for beneficial use of coalbed natural gas produced water often employ a combination of several methods including impoundment, livestock and wildlife watering, irrigation, recreation (**Figure 9**) and dust abatement.

CNG currently supplies 8% of natural gas in the US and is expected to rise to 20% over the next 10 years. This issues a challenge to producers to recover this resource in a cost-efficient, environmentally responsible manner. For land owners, CNG development signifies increased concern for impacts to water quality and soil erosion. It's imperative that we strike a balance between developing resources for energy demands and environmental impacts.


Photo credit: ALL Consulting

Figure 9. Produced water pond.

Acknowledgement

This newsletter is based on: *Handbook on Coalbed Methane Produce Water: Management and Beneficial Use Alternatives,* ALL Consulting, Tulsa, OK (US DOE, BLM, GWPRF). Available at: **www.npto.doe.gov**.

Additional References

– *Handbook on Best Management Practices & Mitigation Strategies for CBM in the Montana Portion of the Powder River Basin*

– *Coal Bed Methane Production Powder River Basin*

– *Resource Assessment and Production Testing for CBM Development in the Illinois Basin*

– *Natural Gas Resources of the Greater Green River and Wind River Basins of Wyoming*

Available at: **www.netl.doe.gov**.

Bureau of Mines data on Coalbed Methane. Available at: **http://oil.server4.com/blmcoalb.htm**.

EPA's Coalbed Methane Outreach Program. Available at: **http://www.epa.gov/coalbed**.

North American CBM Resource Map. Available at: **http://www.eandpnet.com/cbm/ustable.html**.

USGS Coalbed Methane Studies
http://energy.cr.usgs.gov/oilgas/cbmethane/cbmindex.htm.

Upcoming Events/Meetings

February 3-4, 2004, International Association of Drilling Contractors (IADC), *Health, Safety, Environmental and Training Conference and Exhibition* , Houston, TX **www.iadc.org**

February 8-11, 2004, Gas Technology Institute (GTI), *Natural Gas Technologies II-Ingenuity & Innovation*, Phoenix, AZ, (847) 768-0783, **www.gastechnology.org**.

February 18-20, 2004, Society of Petroleum Engineers (SPE), *International Symposium and Exhibition on Formation Damage Control*, Lafayette, LA, **www.spe.org**.

March 3-4, 2004, Petroleum Technology Transfer Council (PTTC) Midwest Workshop, *Produced Water and Associated Issues*, Evansville, IN, (217) 244-9337 **www.pttc.org**.

March 29-31, 2004, Society of Petroleum Engineers (SPE), *International Conference on Health, Safety and Environment in Oil and Gas*, Calgary, AB Canada **www.spe.org**.

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EoE features highlights of DOE's Oil and Gas Environmental Research Program.

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